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ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT
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AGARD ADVISORY REPORT 315

Technical Evaluation Report on the Flight Mechanics Panel Symposium on Piloted Simulation Effectiveness

(L'Efficacité de la Simulation Pilotée)

This Advisory Report was prepared at the request of the Flight Mechanics Panel of AGARD.

NORTH ATLANTIC TREATY ORGANIZATION

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Technical Evaluation Report on the Flight Mechanics Panel Symposium on Piloted Simulation Effectiveness

(L'Efficacité de la Simulation Pilotée)

by

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This Advisory Report was prepared at the request of the Flight Mechanics Panel of AGARD.

North Atlantic Treaty Organization
Organisation du Traité de l'Atlantique Nord

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Preface

This report evaluates the AGARD Flight Mechanics Panel Symposium on "Piloted Simulator Effectiveness", held from 14th to 17th October 1991, in Brussels, Belgium.

The intention of the Symposium was to assess the benefits and the future potential of flight simulation in contributing to aircraft development, skill training, and mission training, for both fixed wing and rotary wing aircraft. In particular, contributors were asked to compare the results of simulated and real tasks.

The papers were wide ranging and of high quality; several new ideas emerged. The technology of flight simulation has greatly improved since the last FMP Symposium on this topic, in 1985. The emphasis of work relating to fixed wing aircraft has shifted towards systems integration. A greater contribution to helicopter design and clearance is also evident.

Although new visual display devices show great promise for military flight training at high speed, low level, they are not yet fully proven, and it is recommended that an early return is made to the topic of pilot training. Simulator validation and fidelity are also of growing importance.

Préface

Ce rapport évalue le symposium organisé par le Panel AGARD de la mécanique du vol sur le thème "L'efficacité de la simulation pilotée", du 14 au 17 octobre 1991, à Bruxelles en Belgique.

Le symposium a eu pour objectif d'évaluer les avantages et le potentiel futur de la simulation du vol pour le développement des aéronefs, la formation technique et l'entraînement à la mission, et ceci pour les aéronefs à voilure fixe et à voilure tournante. En particulier, il a été demandé aux conférenciers de faire la comparaison entre les résultats obtenus pour des tâches réelles et ceux pour des tâches simulées.

Les communications couvrent un large domaine et sont d'une grande valeur, faisant état, parfois, d'idées nouvelles. Des améliorations considérables ont été apportées aux techniques de la simulation du vol depuis le dernier symposium organisé sur ce sujet par le Panel FMP, en 1985. En ce qui concerne les aéronefs à voilure fixe, les travaux en cours dans ce domaine évoluent vers l'intégration des systèmes. A noter également, l'intérêt accru pour la conception et l'homologation des hélicoptères.

Bien que les nouvelles visualisations soient très prometteuses pour l'entraînement militaire au vol à grande vitesse et à basse altitude, elles n'ont pas encore fait leurs épreuves et il est recommandé de réexaminer, en priorité, la question de l'entraînement des pilotes. Enfin, la fidélité et la validation des simulateurs est également un sujet qui prend de plus en plus d'importance.

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1. Introduction.

From a minor role in aircraft design, development and clearance in the 1950's, flight simulation now has an established part to play. A further and vital contribution to aerospace lies in the use of simulation for crew training in almost all operational tasks. The contribution that flight simulation can make in these areas continues to increase, as the elements used in simulation improve. These improvements stem from developments in non-aerospace activities, such as communications and entertainment, which fund advances in graphics and display technology beyond the resources of flight simulation alone. Similarly, general advances in computing technology meet the need for complex modelling and real-time processing.

In a rapidly changing discipline such as flight simulation, it is important that advances are accessible to workers in the field. AGARD provides the ideal forum for this process, in the form of Symposia and published documents such as Conference Proceedings. The Flight Mechanics Panel devotes a Symposium to Flight Simulation approximately every six years, at which time, new developments can be aired. Because of the rapid progress and the broad scope (even when confined to military applications), the theme for the symposium has to be chosen with care. Should it focus on the technology used to design simulators, or on the facilities to meet users' needs, or on the experiences of operators?. The need for a meeting on Flight Simulation was also appropriate because of the changes which have come to Aerospace since the last meeting in Cambridge in 1986; changes which are having a serious effect in all areas of simulation. World economic recession, political changes in Eastern Europe, and the Middle East conflict have had a profound influence on short term prospects. Research budgets have been cut, Industry is contracting, and the financial pressures on all projects is intense.

It is appropriate, therefore, that the FMP chose as a theme for this meeting "Piloted Simulation Effectiveness". The intent of the Symposium was "to provide information on the benefits and potential that the many elements of simulation technology have to meet the different task requirements during conceptual R&D, aircraft development, skill training, and full mission training. The scope includes both fixed wing and rotary wing aircraft, and their systems." Particularly welcome were papers in which simulated and real tasks were compared, and methods of measuring effectiveness were identified.Also sought was a Keynote address "to give a realistic view of the current capability and shortcomings, and also the future potential of simulation", to be given by a user, rather than a provider, of simulation.

The conference was divided into four sessions; each session devoted to a particular topic. The topics were:

1. Aircraft development,
2. Skill training,
3. Full mission simulation,
4. Research applications.

Two distinguished speakers provided the keynote addresses. Their contributions were complementary. Dipl. Ing. J Heyden, Head of Defence Directorate, Federal Ministry of Defence, Germany, dealt with issues in general: current use and limitations of simulation, and opportunities for greater use in training and aircraft development. Col. R.A Borowski, Head of Flight Dynamics Directorate, Wright-Patterson AFB, USA, gave specific examples of simulation in major aircraft development programs, and commented on the standards and shortcomings from a pilot's point of view, based on personal experience.

The Keynote addresses were unusually informative for this kind of Conference. It is worthwhile, therefore, to re-iterate in this report the main points that were made. This will be followed by a discussion of each of the four sessions listed above.

Attendees at this type of conference are, generally speaking, highly qualified and experienced in their field. They expect to learn something from related disciplines, and hope to extend their specialist knowledge, by listening to presentations, by reading the papers, and by the opportunities afforded for personal contacts. In assessing technical merit, therefore, the following criteria, if not already covered by the standard advice given by AGARD to authors, should be applied. Do the papers cover new ground? Do they address the advertised issues? Do they contain sufficient detail to allow their results to be duplicated? Do they give references? And does the spoken version hold the attention of the audience?

2. Key Issues.

H. Heyden defined the two areas in which piloted simulators are used, as follows

Use of Piloted Simulation for Qualification and Training	Use of Piloted Simulation in Verification Testing
* Cockpit Procedure & Proficiency Training	* Definition of Handling Qualities Requirements
* Emergency Procedure Training	* Flight Control and Sub-system Assessment Modification and Up-grading
* Crew Co-ordination & Mission Management Training	* Flight Vehicle Sub-system Acceptance Testing and Certification
* Type and Weapons Training	* Development of Certification Standards
* Familiarisation with New Technologies (Automation)	* Validation of Design and Systems Capabilities for Contractor Selection
* Low Level Flight & Mission Rehearsal Training	

It will be seen that the papers presented, listed in the Appendix address most, if not all, of these topics. He also defined the critical factors concerning military flight operations in Europe, as follows

Critical Issues of Military Flight Operations in Europe

* Flight Restrictions due to
  - Limited Combat Training Ranges
  - Dense Air Traffic
  - Flight Safety Aspects (Air Crashes)

* Flying Hour Reductions due to
  - Declining Budgets
  - Rising Costs of Flight Operations

* German Ban on Low Flying due to
  - Greater Environmental Awareness (Noise Annoyance)
  - Increasing Public Reluctance and Opposition

* Adverse Effect on Aircrew Morale?

The question which H. Heyden poses is "to what extent can current standards of flight simulation be used to alleviate the effects of these factors?" Clearly, there are shortfalls, mostly related to pilot acceptance, but research activities are underway to provide solutions. One activity in Germany receiving particular attention is that of simulating high speed, low level flight. This figure lists the key factors in terrain following training simulation.

Terrain Following Training Simulation

General Requirements

* Accurate Modelling of Aircraft and Environmental Dynamics
* Effective Visual Description of Outside World
  - Large Field of View (FoV)
  - High Resolution Computer Generated Imagery (CGI)
* Realistic Motion Environment
  - High Fidelity Motion

Problem Areas
* Simulator Induced Sickness (SIS)
* Neural Mis-Match (eg Neural Storage of Experience)
* Biodynamic Interferences (eg Pilot Induced Oscillations)
* Variability of Information and Control Strategies

Col.Borowski picked up the theme of problem areas, and discussed the standards of simulation currently in use. He looked at devices operating in the United States, from a pilot's point of view. They range from "folding chair" simulators (monitor, joystick, and desk-top computer) to the large dome full projection systems for combat missions.

He reported a simulation of the Harrier on the VMS at NASA Ames, in which a change from motion off to motion on made a marginally flyable task into one which was easy to control, "as if a powerful and effective set of stability augmenters had been engaged". On the Crew Station Research and Development Facility, also at Ames, he flew a simulated helicopter manoeuvring at low level. The fixed base simulator uses the CAE helmet to provide a wide angle display. He found an overwhelming sensation of motion, and could distinctly feel the forces applied to his body. In resolving the basis of these sensations, he experienced motion sickness. In fairness to the equipment, he was outside its intended regime of operation.

He also drew our attention to other successful simulator programmes- the agility work in the domes at NASA Langley, the development of the HL20 "space taxi" flying qualities, also at Langley, the NASA Dryden work on minimum reversionary standards of flight controls, and the in-flight simulators funded by Wright-Patterson AFB. A new addition, VISTA (a modified F-16) is scheduled to fly in November 1991. His final examples were the simulations used to assist in the development and clearance of aircraft such as the X-29 and the STOL F-15.

To complete the summary of the key issues, it is instructive to look at H. Heyden's recommendations, which took the form of a challenge to the assembled experts.

Recommendations

Challenges to the AGARD and Expert Community here today concerning Aspects of Affordability:

* What are the Minimium Equipment Requirements for
  - Development and Verification Simulation
  - Pilot Training Simulation
  - Complex Air Warfare Simulation?

* Where are Cost-Effective Enabling Technologies to improve Simulator Fidelity?

* What Measures must be taken to increase the Pilot Acceptance of Training Simulation?

* What Means of Simulation Facility Concentration and Standardisation may improve NATO Military Operational Effectiveness?

3. Technical Programme.

3.1 Session 2. Aircraft Development.

The session consisted of seven papers, two of which related directly to helicopters, and three to fixed wing aircraft. As evidence of the growing contribution that simulation makes to helicopter design and development, the helicopter related papers gave a comprehensive picture of progress in that field, whereas the fixed wing papers each dealt with a specific examples of aircraft systems which were developed or cleared by simulation in support of flight test.

Paper 5 covers the difficult area of helicopter modelling. The aerodynamic model is dominated by the forces and moments generated by the rotors,and the complex flow patterns they induce. The paper describes in detail the relative merits of three levels of rotor modelling- linear analytical, hybrid (rotormap), and blade element. The validation of the models is then discussed, and flight comparisons are presented for a variety of manoeuvres. Finally, examples of helicopter simulations at McDonnell Douglas and at NASA Ames are described. Paper 6, from MBB, describes the simulators they used to develop their range of rotary wing aircraft, with useful comment on the hardware standard needed to address a particular area of interest. The importance of both objective validation and subjective validation of the simulator is stressed, and interesting observations are made on the attitude of their test pilots to flight simulation (reflecting a general feeling at the Symposium, that pilots still see simulators as useful but artificial). The paper concludes with sound advice to all users of research and development simulators.

The papers relating to fixed wing aircraft (3,4, and 8) each deals with a specific aircraft, and the support given to flight test by simulation, in clearing a system. Paper 3 gives a clear account of a violent pitch oscillation which occurred on a US fighter during practice air combat, and how a fixed base simulator contributed to the investigation of the problem and its solution. The cause of the pio, control surface rate limiting, was identified quickly, because good flight records of the incident were available. The standard of the aircraft model in the simulator was sufficiently accurate to achieve a near match, once the right combinations of control inputs were found. It is concluded that ground based simulation is now an essential adjunct to flight testing.

Paper 8, also from a flight test centre, gives a similar message. In this case, the task was to develop an active ground-avoidance system for the F -18. The simulator was used to reduce greatly the flight test programme, by isolating critical cases, and by eliminating options on the basis of pilot opinions obtained from the simulator. Papers 3 and 8 both stressed the value of the simulator in reducing the risk of flight testing.

The third fixed wing paper (paper 4) gave a good overview of the development of the digital flight control system for the A 320. Some of the issues have been presented previously: side stick implementation, manoeuvre demand laws, and protection methods. However, the discussion on the implications of digital flight control on training simulator issues is timely. Aerospatiale believe that the use of the actual system hardware and software is essential- stimulation rather than simulation.

The message of paper 7 was that modelling and real time simulation plays a vital part in the development of radar-based terrain avoidance systems. The problems and benefits are well catalogued, but the paper contains neither examples of a radar system, nor simulator to flight comparisons. Nor is the part played by the pilot covered in this paper.

The last paper in the session (paper 9) was a report on the progress of the FMP Working Group 16, on Simulation in Aircraft and Systems Flight Clearance. Validation of the simulator is a key issue, and the areas where difficulties arise are discussed. These include obtaining relevant flight data, computer modelling (real time and non-real time), visual and motion simulation deficiencies, and software verification. The case is made for greater use of simulators for certification of military aircraft, because the cost savings are potentially greater than those currently achieved by the use of simulation in the certification of civil aircraft.

3.2 Session 3. Skill Training.

To embrace all the papers given in this session, a loose definition of "skill training" has to be applied. For example, paper 14, from Alenia, might easily have been placed in the section on Aircraft Development, in spite of the reference to training in the title. Paper 13 qualifies for this session only by remembering that the reported activity contributes to the skill of test pilots. Nevertheless, all the papers were well prepared and presented, and contained interesting information.

Paper 10, from NLR, deals with the basic issues of training. First, it discusses the deficiencies of present standards from a pilot's point of view (credibility). The next point is that unless pilots react in the simulator in the same way as they do in the aircraft, training effectiveness is compromised. An example is given of different arousal levels in simulators and flight, by showing heart rate measurements at take off. The issue of realism is raised, and whether it is possible to induce a state of anxiety in simulators. The way ahead is to expand research activities, and the available mechanisms are listed. The final suggestion, that new training simulator configurations should first be tested in a research simulator, is clearly meant as a debating point.

Paper 11 describes an ambitious new facility, the Simulator Complexity Test Bed, for the US Army at Fort Rucker. It will be used to study issues relating to the transfer of training, simulator fidelity, and tactics. Customer acceptance is underway at CAE; delivery is in six months. Features are configurable hardware, two cockpits, operator's station, red/blue team station, 10 channels of ESIG 6000 visual image generation, and eye slaved FOHMED helmet displays.

An aeromedical expert from the Netherlands presented paper ... The question it poses is whether or not spatial disorientation can be induced in a simulator which is able also to represent typical pilot training tasks. Serious losses of aircraft and pilots are occurring due to loss of consciousness and disorientation. The solution seems to lie in better ground based training. This challenge coincides with the call from other speakers for greater realism, and the need to simulate stressful situations.

Test pilots under training at Edwards Air Force Base learn the fundamentals of flight control and flying qualities with the help of both ground based and in-flight simulators (paper 13). The value of the method is emphasised, and the ease with which the effect of aerodynamic derivative changes can be demonstrated. The work described, however, does not break new ground, and misses the opportunity to report subjective comparisons by pilots between fixed base and in flight simulation.

Flight simulation was used extensively for the development of Italy's AM-X, and for pilot training. Many examples are given in paper 14 of problem areas which benefitted from ground based simulation- high angle of attack flight, spinning, nav/attack, weapon delivery, hud, and autopilot. Simulator/ flight comparisons are also included. Prior to delivery of the training simulator, the R and D simulator was also used for operational pilot conversion. Of particular value was the demonstration of a "pop-up" attack profile which avoids negative g , and so reduces roll-induced sideslip. The presentation concluded with a video. Of particular note was the value of the simulator in recontructing and visualising the developed spin. The view from the cokpit, and a computer generated view of the aircraft were seen simultaneously.

3.3 Session 4. Full Mission Simulation.

Since the 1987 FMP meeting devoted to Simulation, the need for full mission simulation has become more pressing, and the equipment standard to simulate a full mission has become available. Although "full mission" is an open-ended definition, the characteristic that distinguishes a full mission simulator from an operational flight trainer or a development simulator, is the need to provide inter-active opponents. The type of threat and the number of players lead to complex scenarios which can include friendly forces acting in support, and environmental factors such as counter-measures.

The intention of the session was to describe the progress which has been made in this important area, particularly with respect to the means of establishing accuracy and validity. The first two contributors (papers 15, 16) described two large facilities for research: the Engineering Development Full Mission Flight Simulator, at Sikorsky, USA, for helicopter operations, and the USAF Flight Dynamics Directorate's Ground Based Air-combat Simulation of ICAAS (Integrated Control and Avionics for Air Superiority) at Wright-Patterson AFB. Both facilities represent substantial investments in simulation, and each paper gives an excellent description of the philosophy behind the project, the structure, and the hardware components. Neither paper, however, addressed the questions "what problems were solved along the way?" and "how well does it perform?". In both cases, it is likely that the answers would be "early days"; we will have to wait for future meetings to hear about validation and use.

The next two papers (17, 18) also had wide appeal. The economic factors referred to in Section 1 have had a particularly depressing effect on the manufacturers of military training simulators. As the tide turns, and customers return, they will wish to offer new technologies with confidence. Both papers discuss exciting visual display developments: the British Harrier GR 5/7 simulator uses the Singer Esprit area of interest display, and the German Tornado Test bed to evaluate the simulation of high speed low level flight uses the CAE FOHMED helmet display. Both programmes are the culmination of extensive development, and success will dictate future procurements. Delegates were therefore hoping for news of progress in both projects. Both papers describe clearly the concepts and hardware, and the speakers answered questions honestly, but the big questions, "how acceptable to operational pilots are these simulators?" and "what aspects need improvement?", have to be answered at future meetings.

The last two papers in this session (19, 20) do contain information about the reactions of pilots to full mission simulation. Paper 19 describes MBB's facilities for the study of BVR combat. A link to the domes at IABG is available, to provide up to 2v2 manned combat capability. Reported results include pilot comments on the cockpit display problem of presenting complex scenario information without confusing the pilot. He wants to make the decisions, but needs help in priorities. The paper also says that in the simulator trials of BVR combat, their AMS (Attack Manoeuvring System) produced an increase in kill ratio by a factor of three.

Paper 20 describes the US Navy's V-22 Osprey Simulator at Patuxent River. Unlike its predecessors, most of the paper is devoted to the objective and subjective validation of the simulator. Time histories are included comparing simulated with actual flight, and comments are made about where the simulator is representative of the aircraft, and the areas where improvements are needed (ship airwake modelling, and shipboard visual cueing). Evidence of the value of the simulator lies in the completion of deck landing trials of a prototype aircraft without mishap.

3.4 Session 5. Research Applications.

The final session consisted of ten papers covering a wide variety of topics to which simulation studies have contributed. These include civil aircraft flying qualities, military aircraft flying qualities, rotary wing aircraft flying qualities, cockpit displays, avionics, and pilot cueing.

Paper 21, from ONERA, gives an overview of three investigations to select preferred primary flight control laws by ground based simulator trials. The investigations span a number of years, and so the title "new concepts" could be challenged; even so, the paper is a useful and thorough documentation of the use of simulation in this vital area of design. Two of the investigations were part of a GATEUR programme, involving co-operation between research centres in four countries. Their successful conclusion is an encouraging pointer to the form that future research may take (other speakers made reference to the European EUCLID programme, in which Governments and Industry are to co-sponsor research). The conclusion of the paper is that these programmes benefitted from having two levels of simulation: a simple standard, for preliminary investigations, and a more complete and representative simulator, for fine tuning of preferred options.

Researchers in flying qualities are still pre-occupied with the influence of flight control system time delays and lags. It is understandable, in the sense that current hardware standards in ground based simulators often suffer from delays which could compromise their use for certain investigations. The three papers on this topic (23, 24, and 27) all reported recent and significant work. Paper 23 contains a valuable analysis of helicopter flying quality assessments made on the VMS at Ames. For a baseline set of vehicle dynamics, variations were made to the dynamic response of the simlator's visual and motion systems, which the pilots interpreted as changes to the fly .. qualities. Two of the significant findings were: first, that there is a need to tailor the dynamics of the motion system to suit the task. (Although the motion system improved ratings for all the task simulated, this result may imply that for a benign task, there would be no need for motion cues). secondly,there was evidence to suggest that with motion on, it is preferable to have some time delay in the visual system, to minimise the mismatch between the visual and motion responses.

The primary purpose of the work described in paper 24 was to validate a simulation of a landing approach with a lateral off-set on the Bedford Large Motion System, against the same task in flight, using Calspan's Learjet. The vehicle dynamics were degraded progressively, by introducing a lag in the roll command path. Results from fixed base, motion, and in-flight simulations were compared. The presentation was enhanced by a video film, showing approaches with the pilot rating super-imposed.

The significance of time delays on transport aircraft controls (as opposed to fighter controls) was covered in paper 27, with supporting data from a moving base simulator. Several interesting ideas are put forward. It appears that pre-filter lags degrade transport aircraft handling less than fighter handling. (This may explain why airline pilots are less critical of their simulators than military pilots are of theirs). A rationale is given for the variations of pilot ratings with time delay from different experiments.

Simulation and flight are compared in paper 28, in terms of performance and pilot opinion, for a helicopter doing IFR landing appraches. Other conditions tested include motion on/off, and IFR/VFR flight. In the concluding remarks it is noted that validating the simulator with the real helicopter needed both objective testing (flight records), and subjective testing (pilot fine tuning) The task was found to be insensitive to simulator configuration (motion on/off, visual on/off), which seems to correlate with the implication of the reduced need for motion cues when the task is benign, as discussed in paper 23

A further comparison between simulator and flight is given in paper 30, for two fixed wing aircraft. In this case, the simulator was fixed base. Considerable attention was given to the details of the scene presented to the pilot by the visual display, particularly during the landing flare. Two types of aircraft were simulated, and a close correlation with flight was achieved. In the flared landings, mean sink rate at touchdown was lower in the simulator than in flight, due, said the author, to the presence in the flight results of atmospheric disturbances.

Several previous speakers had emphasised the importance of ground based simulators in the clearance of flight control systems. Paper 26 makes the same point, except that the flight control system is also in a simulator-the DLR Advanced Technologies Testing Aircraft System, ATTAS. The ATTAS has a complex digital fly by wire system. For testing and validation, a ground based simulation was found to be essential. The ground modelling included parameter identification from ground records. A further use of the simulator is to allow test pilots to prepare for airborne evaluations.

Papers were also presented on advanced cockpit displays. Research into displays for transport aircraft will be possible on the Deutsche Airbus Facility, described in paper 25. It uses the concept of a virtual cockpit, in which software is used to generate display formats, rather than hardware, resulting in large cost savings, flexibility, and versatility. The development of cockpit displays for low level high speed flight is the topic of paper 22, from Dassault. The displays were designed to give a perspective view of the terrain ahead of the aircraft, viewed by the pilot on a colour CRT in the cockpit. Many parameters, such as field of view, scene complexity, and display update rate were evaluated in a Ratale simulator. The use of the simulator greatly reduced flight testing, and prepared the way for the specification of airborne equipment. Film of the simulation was shown.

The expanding use of flight simulation was also seen in the the large scale testing described in paper 29. The manned simulator programmes at NASA Langley on fighter manoeuvring at high angle of attack, and the criteria relating to agility were described. Correlation with full scale flight results is the primary means of validating the simulator results. The questions of pilot experience, and pilot rating scales, are also addressed.

4. Conclusions.

4.1. The high standard of technical papers which has characterised AGARD FMP meetings over the years was maintained at this Symposium. The papers were broad in scope, well presented, and well received by the delegates. It was a testimony to all contributors that all the papers were given - the recent trend at other conferences has been to a significant number of "no shows". Attendance was good, and the facilities were excellent.

4.2. Since the last FMP Symposium on Flight Simulation, at Cambridge, UK, in 1985, several advances in simulation technology were revealed. Notable was the reported use of simulators in helicopter design, development, and flight clearance. There has also been a shift in the emphasis of work on fixed wing aircraft, from flying qualities and flight mechanics, towards systems development and certification. Full mission simulation is increasingly prevalent in R and D, and will soon be established as a contributor to operational crew training.

4.3. A broader spectrum of simulator devices is emerging, ranging from low cost, desk-top devices, to high cost, fully capable simulators. Each device has a particular part to play in the varied applications of simulation. At the top end of the range, the realism of the simulation still leaves room for improvement, particularly in representing the more demanding regimes of military aircraft operations.

4.4 Additional information emerged at the Symposium concerning the techniques which limit the acceptance of simulation in some applications: visual image generation and display, motion system performance, accuracy of modelling, and temporal fidelity. All of these issues are complex and conditional, so that simple criteria of acceptability (are motion cues necessary?, will a time delay intrude?) can only be defined for particular circumstances - flight condition, task, environment, and pilot background. As flight simulator usage broadens into new areas, research to define standards as a function of application is urgently needed, until technology advances provide components which faithfully mime the real world.

4.5 The theme of the meeting, piloted simulator effectiveness, was well covered, but too much time was devoted to the description of facilities, without information on their effectiveness. This issues gave cause for concern to Mr A M Cook, the author of the Technical Evaluation Report of the 1985 meeting, at which 7 papers out of 26 described facilities (Reference). This Symposium contained a similar proportion. He went so far as to recommend that the FMP should set up a Specialists Group to meet regularly on the topic, and "to diminish the presentation at formal symposia of the more mundane aspects of facility description." There are practical difficulties to the implementation of Mr Cook's recommendation, but the Flight Mechanics Panel can improve matters, by stricter control of paper selection.

4.6 The keynote speaker who had the first word should also have the last. Few of the delegates would disagree with H. Heyden's last slide.

Conclusions

* AGARD plays an Indispensable Role in the Development of Piloted Simulation

* AGARD provides a Cost-Effective Technical Forum to the NATO Piloted Simulation Community

* AGARD should continue to Accumulate Multi-disciplinary Simulation Expertise in its various Technical Panels

5 Recommendations.

The goals that were set for the aerospace industry in the 60's and 70's were challenging, and required extensive research and development. Many organisations contributed, funding was available, and information was freely exchanged. The past decade has seen this situation change: fewer projects, a contracting industry, and less R & D funding. Research programmes take longer to implement, are subject to commercial scrutiny, and the early release of information is restrained by considerations of Industrial Property Rights (IPR). Consequently, the work of AGARD as a platform for the dissemination of information is more important than before. AGARD conferences act as a catalyst for individuals and organisations to make their results available, and for knowledge to be shared. Although the continuing importance of AGARD applies to all the Flight Mechanics Panel interests, it has a special significance to the discipline of Flight Simulation, because of its expanding range of application. This Symposium has clearly shown the progress in the last six years, and the expectations for the future.

Papers given at the Symposium indicated that

1) the use of flight simulation has expanded considerably in the development of fixed and rotary wing aircraft. In particular, testing and flight clearance of airframe and systems is now dependent on simulator activities. Confidence in the techniques is established, and benefits in cost, timescale, and risk are proven.

2) the use of flight simulation for the training of military crews does not receive the same wide acceptance, and falls short of the use of simulators by the airline operators to train civil crews. Reasons for this difference were seen at the Symposium: the more demanding scenarios, the lack of realism for certain tasks, and the supposed threat to flying hours.

The military crew training situation could easily change, as current activities bear fruit. In addition to the German MoD research on simulating high speed low level flight, the British Harrier simulator, and the US Army facility at Fort Rucker, experience may soon be reported on simulators for initial pilot training, on the use of crewroom training aids, on projected wide angle displays, on more detailed modelling methods, and the use of structured training. There is therefore a strong case for the Flight Mechanics Panel to return to the topic of Training before 199[illegible].

Other areas which the FMP should monitor were identified at the Symposium. The increasing use of flight simulation by the R & D community makes the methods of acceptance and validation a key topic. The results from WG 16 will be published in 1992; it remains to be seen whether this work will cover the validation of Full Mission Simulators. The value of such simulators is directly related to their ability to create realistic scenarios.

The issue of realism also appeared at the conference. Realism is an abstract quality, and the call for it strengthens the case for subjective as well as objective validation. Can realism be categorised in a manner similar to that used in flying quality assessments, the rating scale, which the FMP did so much to promote thirty years ago? Or does a measure of realism require a different approach?

There is possibly a link between the development of more realistic simulators and the reported occurrences of "simulator sickness". Several speakers at the conference touched on the topic of the possibility of adverse physiological effects on the pilot in some simulators. There is a need to identify the safe ground, where simulators can continue to be used without problems of this nature, until a better understanding of the mechanisms can be found. Perhaps WG 20 will contribute to the discussion.

Finally, the conditional relationships between simulation standard and application emerged from the contributions of several speakers. Research should be encouraged to establish these relationships in a more formal manner, as part of the move to improved methods of validation.

6. Reference.

AGARD-AR-234 "Technical Evaluation Report on the Flight Mechanics Panel Symposium on Flight Simulation".

Anthony M Cook October 1986

ppendix.

rogramme - FMP Symposium on Piloted Simulation Effectiveness.

onday 14 October

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pening Ceremony

Session 1 - Keynote Addresses
Chairmen: A.A. Woodfield (UK), S. Baillie (Ca)

aper

. Opportunities for Flight Simulation to Improve Military Operational Effectiveness
Ministerialdirektor J. Hyden, Ministry of Defence (GE)

. Piloted Simulation in Research and Development
Col R.A. Borowski, Wright-Patterson Laboratory (US)

Session 2 - Aircraft Development (Part 1)
Chairmen: J. Tresset (FR), F. Sella (IT)

. Use of Simulation in Flight Control Identification and Solution Verification
K. Keller, D. Jansen & A.Asay, Edwards Air Force Base (US)

. Digital Flight Control and Piloted Simulation
D. Chatrenet, Aerospatiale (FR)

. The Application of Flight Simulation Models in Support of Rotorcraft Design and Development
P. Shanthakumaran, D. Banerjee, McDonnell Douglas Helicopters (US)

Experience with Piloted Simulation in the Development of Helicopters
M. Obermayer, K. Kampa, W. Dohnel, A. Faulkner, MBB Helicopters (GE)

Session 2 - Aircraft Development (Part 2)
Chairmen: M. Tischler (US), J. Martinez-Garcia (SP)

. Usefulness of Interactive Real-Time Simulation for Development of Radars in Terrain Following Functions
(Interet des simulations temps reel interactives pour le developpment
de la fonction suivi de terrain des systems radar)
T. Martinet, Thomson-CSF (FR)

. Use of High Fidelity Simulation in the Development of an F/A-18 Active Ground Collision Avoidance System
T.R. Fitzgerald, M.T. Brunner, NATC (US)

. Simulation for Aircraft and Systems Flight Clearance (AGARD FMP WG16)
A.A. woodfield, J.R. Hall, DRA (UK)

uesday 15 October

Session 3 - Skill Training
Chairmen: B. McCormick (US), Z. Ghikas (GR)

0. Aircraft Simulation and Pilot Proficiency: from Surrogate Flying towards Effective Training
P.G.A.M. Jorna, E.R.A. van Kleef, W.P. de Boer, NLR (NE)

1. The Use of a Dedicated Test Bed to Evaluate Simulator Training Effectiveness
D. Kurts, CAE (CA) & C.P. Gainer, Fort Rucker (US)

2. G-Tolerance and Spatial Disorientation. Can Simulation Help Us?
J. Smit & R.E. van Patten, NLRGC (NE)

3. Use of Ground Simulation in the USAF Test Pilot School Curriculum
S. Louton & D. Ringenbach, Edwards AFB (US)

4. Aeritalia AM-X Flight Simulator from Coarse R & D to Full Mission Trainer
A. Armando, P. Castoldi, F. Fassi, Alenia (IT)

Session 4 - Full Mission Simulation
Chairmen: J.A. Mulder (NE), K. McKay (UK)

5. Full Mission Simulation. A View into the Future
M. Ferranti, Sikorski Aircraft (US)

6. Full Mission Simulation for Research and Development of Air Combat Flight Management Systems
D.G. Goddard, J.M. Zeh, Wright Lab. (US)

17. The Evaluation of Simulator Effectiveness for the Training of High Speed, Low Level, Tactical Flight Operations
A. Morris, CAE (CA)

18. Harrier GR5/7 Mission Simulator for the Royal Air Force
P. Jackson, Link-Miles & B.R. Clifford, MoD (UK)

Wednesday 16 October

19. Development and Evaluation of an "Attack and Maneuvering System" with Combat Development Simulators as Main Development Tool
H. Eibl, H.G> Offenbech, H.W. Pongratz, MBB (GE)

20. Shipboard Mission Training Effectiveness of the Naval Air Test Center's V-22 Government Test Pilot Trainer
C. Miller, G. Vandervliet, NATC (US)

Session 5 - Research Applications (Part 1)
Chairmen: G. Schaenzer (GE), G.H. de Leeuw (CA)

21. Use of a Research Flight Simulator for Development of New Concepts of Mission Oriented Flight Control Systems
(L'emploi d'un simulateur de vol de researche pour le developpement de nouveaux concepts dans le domaine des systems de commandes de vol orientes missions)
P. Guicheteau, ONERA (FR)

22. Le Role de la Simulation pour l'Etude d'Aide au Pilotage par Imagerie Synthetique (APIS)
R. Miginiac, P. Pagnier, P. Larroque, Dassault Aviation (FR)

Technical Tour - SONACA, Gosselies

Thursday 17 October

23. The Use of Ground Based Simulation for Handling Qualities Research: A New Assessment
D. Mitchell, *Systems Technology Inc.*, R. Hoh, *Hoh Aeronautics Inc.*,
A. Atencio, Jr., D.L. Key, US Army, Ames Research Center (US)

24. Initial Validation of an R & D Simulator with Large Amplitude Motion
A.D. White, J.R. Hall, B.N. Tomlinson (UK)

Session 5 - Research Applications (Part 2)
Chairmen: J. van Doorn (NE), D. Agneessens (BE)

25. Use of a Virtual Cockpit for the Development of a Future Transport Aircraft
K. Kricke, W. Quellmann, Deutsche Airbus (GE)

26. The Role of Systems Simulation for the Development and Qualification of ATTAS
D. Hanke, H.-H. Lange, P. Saager, DLR (GE)

27. The Use and Effectiveness of Piloted Simulation in Transport Aircraft Research and Development
J. Hodgkinson, K.F. Rossitto, E.R. Kendall, Douglas Aircraft Co. (US)

28. The Evaluation of IFR Approach Techniques: Generic Helicopter Simulation compared with Actual Flight
L.D. Reid, S. Advani, J.H. de Leeuw, University of Toronto (CA)

29. Application of Piloted Simulation to High Angle-of-Attack Flight Dynamics Research for Fighter Aircraft
M.E. Ogburn, J.V. Foster, K.D. Hoffler, NASA Langley (US)

30. Effective Cueing during Approach and Touchdown - Comparison with Flight
P. Beckett, British Aerospace (UK)

Closing Ceremony

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14. Abstract

This report evaluates the AGARD Flight Mechanics Panel Symposium on "Piloted Simulator Effectiveness", held from 14th to 17th October 1991, in Brussels, Belgium.

The intention of the Symposium was to assess the benefits and the future potential of flight simulation in contributing to aircraft development, skill training, and mission training, for both fixed wing and rotary wing aircraft. In particular, contributors were asked to compare the results of simulated and real tasks.

The papers were wide ranging and of high quality; several new ideas emerged. The technology of flight simulation has greatly improved since the last FMP Symposium on this topic, in 1985. The emphasis of work relating to fixed wing aircraft has shifted towards systems integration. A greater contribution to helicopter design and clearance is also evident.

Although new visual display devices show great promise for military flight training at high speed, low level, they are not yet fully proven, and it is recommended that an early return is made to the topic of pilot training. Simulator validation and fidelity are also of growing importance.

The full texts of the papers presented at this Symposium are published in AGARD-CP-513.

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The papers were wide ranging and of high quality; several new ideas emerged. The technology of flight simulation has greatly improved since the last FMP Symposium on this topic, in 1985. The emphasis of work relating to fixed wing aircraft has shifted towards systems integration. A greater contribution to helicopter design and clearance is also evident.

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